

PROBING PATTERNS OF SUPERSYMMETRY BREAKING USING PHENOMENOLOGICAL CONSTRAINTS*

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Specific models of supersymmetry breaking predict relations between the trilinear and bilinear soft supersymmetry breaking parameters A_0 and B_0 at the input scale. Models with $A_0 = B_0 + m_0$ as well as the simplest Polonyi model with $A_0 = (3 - \sqrt{3})m_0$ are discussed. In such cases, the value of $\tan\beta$ can be calculated as a function of the scalar masses m_0 and the gaugino masses $m_{1/2}$, and various experimental constraints can be applied to constrain it.

One of the most important and least understood problems in the construction of supersymmetric models is the mechanism of supersymmetry breaking. In the context of constrained MSSM (CMSSM) it is assumed that the soft supersymmetry-breaking masses m_0 , $m_{1/2}$ and the trilinear soft parameter A_0 , have universal values at the GUT scale. One then analyzes the impacts of the different phenomenological limits on the allowed values of $m_{1/2}$ and m_0 as functions of $\tan\beta$, assuming some default value of A_0 and determining the Higgs mixing parameter μ and the pseudoscalar Higgs mass m_A by using the electroweak vacuum consistency conditions^{1,2,3,4,5,6}. On the other hand, specific models of supersymmetry breaking predict relations between these different soft supersymmetry-breaking parameters. For example, certain ‘no-scale’ models⁷ may predict $m_0 = 0$ at the Planck scale. Here we analyze (for details see Ref.²) a different question, namely the consistency of some proposed relations between m_0 , A_0 and B_0 using for convenience $A_0 = \hat{A}m_0$, $B_0 = \hat{B}m_0$. A generic minimal supergravity (SUGRA) model⁸ prediction is that $\hat{B} = \hat{A} - 1$ ⁹, and the simplest Polonyi model¹⁰ predicts that $|\hat{A}| = 3 - \sqrt{3}$ ¹¹.

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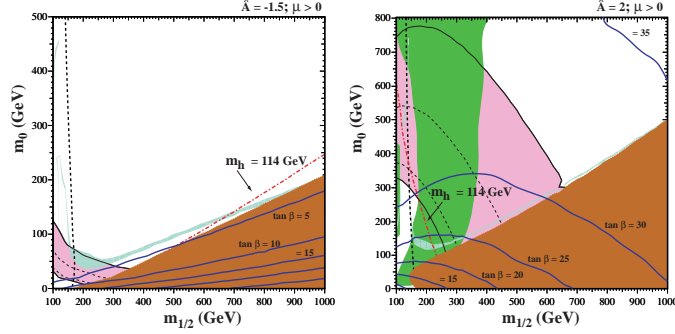


Figure 1. Examples of $(m_{1/2}, m_0)$ planes with contours of $\tan \beta$ superposed, for $\mu > 0$ (a) $\hat{A} = -1.5$, and (b) $\hat{A} = 2.0$, with $\hat{B} = \hat{A} - 1$. In each panel, we show regions excluded by various constraints as they are described in the text.

For a specific value of \hat{A} and \hat{B} , these relations may be used to replace an *ad hoc* assumption on the input value of A_0 . For any given value of $m_{1/2}$ and m_0 , these constraints are satisfied for only specific values of $\tan \beta$. Therefore, the results of imposing these SUGRA relations may conveniently be displayed in a single $(m_{1/2}, m_0)$ plane across which $\tan \beta$ varies in a determined manner. Furthermore, the phenomenological constraints on $m_{1/2}$ and m_0 can be used to provide both upper and lower limits on the allowed values of $\tan \beta$ ².

We display in Fig. 1 the contours of $\tan \beta$ (solid blue lines) in the $(m_{1/2}, m_0)$ planes for selected values of \hat{A} , \hat{B} and $\mu > 0$. Also shown are the contours where $m_{\chi^\pm} > 104$ GeV (near-vertical black dashed lines) and $m_h > 114$ GeV (diagonal red dash-dotted lines). The excluded regions where $m_\chi > m_{\tilde{\tau}_1}$ have dark (red) shading, those excluded by $b \rightarrow s\gamma$ have medium (green) shading, and those where the relic density of neutralinos lies within the WMAP range $0.094 \leq \Omega_\chi h^2 \leq 0.129$ have light (turquoise) shading. Finally, the regions favoured by $g_\mu - 2$ at the $2\text{-}\sigma$ level are medium (pink) shaded.

As seen in panel (a) of Fig. 1, when $\hat{A} = -1.5$, close to its minimum possible value, the contours of $\tan \beta$ rise diagonally from low values of $(m_{1/2}, m_0)$ to higher values, with higher values of $\tan \beta$ having lower values of m_0 for a given value of $m_{1/2}$. The $m_h = 114$ GeV contour rises in a similar way, and regions above and to the left of this contour have $m_h < 114$ GeV and are excluded. Therefore, only a very limited range of $\tan \beta \sim 4$ is compatible with the m_h and $\Omega_{CDM} h^2$ constraints. At lower values of \hat{A} ,

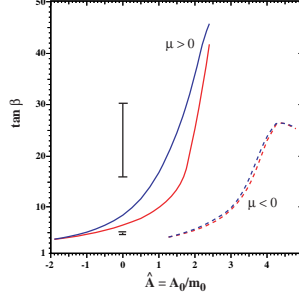


Figure 2. The ranges of $\tan\beta$ allowed if $\hat{B} = \hat{A} - 1$ for $\mu > 0$ (solid lines) and $\mu < 0$ (dashed lines). The Polonyi model corresponds to $\hat{A} \simeq \pm 1.3$. Also shown as ‘error bars’ are the ranges of $\tan\beta$ allowed in the no-scale case $\hat{A} = \hat{B} = 0$ for $\mu > 0$ (upper) and $\mu < 0$ (lower).

the slope of the Higgs contour softens and even less of the parameter space is allowed. Below $\hat{A} \simeq -1.9$, the entire $m_{1/2} - m_0$ plane is excluded. In panel (b) of Fig. 1, when $\hat{A} = 2.0$, close to its maximal value for $\mu > 0$, the $\tan\beta$ contours turn over towards smaller $m_{1/2}$, and only relatively large values $25 \lesssim \tan\beta \lesssim 35$ are allowed by the $b \rightarrow s\gamma$ and $\Omega_{CDM}h^2$ constraints, respectively.

We note the absences of both the funnel and the focus-point regions. In the case of the funnel, this is due to the relatively small values of $\tan\beta$ allowed in the class of models considered here: we recall that the funnel region appears only for large $\tan\beta \gtrsim 45$ for $\mu > 0$ and $\tan\beta \gtrsim 30$ for $\mu < 0$ in the CMSSM. Moreover, as A_0 is increased, the focus point is pushed up to higher values of m_0 . Here, with $A_0 \propto m_0$, the focus-point region recedes faster than m_0 if \hat{A} is large enough, and is therefore never encountered.

It became clear that only limited ranges of $\tan\beta$ are consistent with the phenomenological constraints within any given pattern of supersymmetry breaking. We display in Fig. 2 the ranges of $\tan\beta$ allowed as a function of \hat{A} . We find consistent solutions to all the phenomenological constraints only for $-1.9 < \hat{A} < 2.5$, over which range $3.7 < \tan\beta \lesssim 46$. In the specific case of the simplest Polonyi model with positive $\hat{A} = 3 - \sqrt{3}$, we find $11 < \tan\beta < 20$, whereas the range in $\tan\beta$ for the negative Polonyi model with $\hat{A} = \sqrt{3} - 3$, is $4.4 - 4.6$. The corresponding results for $\mu < 0$ are $1.2 < \hat{A} < 4.8$ over which range $4 < \tan\beta \lesssim 26$. The range of \hat{A} is shifted, and the range of $\tan\beta$ reduced, as compared to the case of $\mu > 0$. In particular, the negative Polonyi model is disallowed and the positive version is allowed only for $\tan\beta \sim 4.15$.

We have shown that only a restricted range of $\tan\beta$ is allowed in any specific pattern of supersymmetry breaking. We have illustrated this point by discussions of minimal SUGRA models with $\hat{A} = \hat{B} + 1$ and no-scale models with $\hat{A} = \hat{B} = 0$, but the same comment would apply to other models of supersymmetry breaking not discussed here.

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